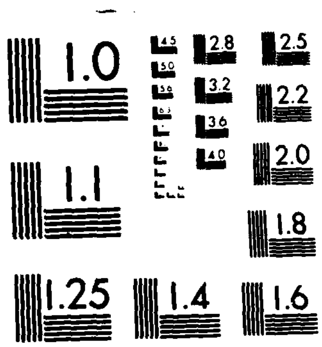
AD-A126 903 INITIAL DEVELOPMENT OF AN AIR DEPLOYED ACOUSTIC MOORING (ADAM)(U) OCEAN ELECTRONIC APPLICATIONS INC KEY BISCAYNE FL E J SOFTLEY MAR 83 OEA-83D5/01 1/1

UNCLASSIFIED N00014-81-C-0687 F/G 13/10 NL

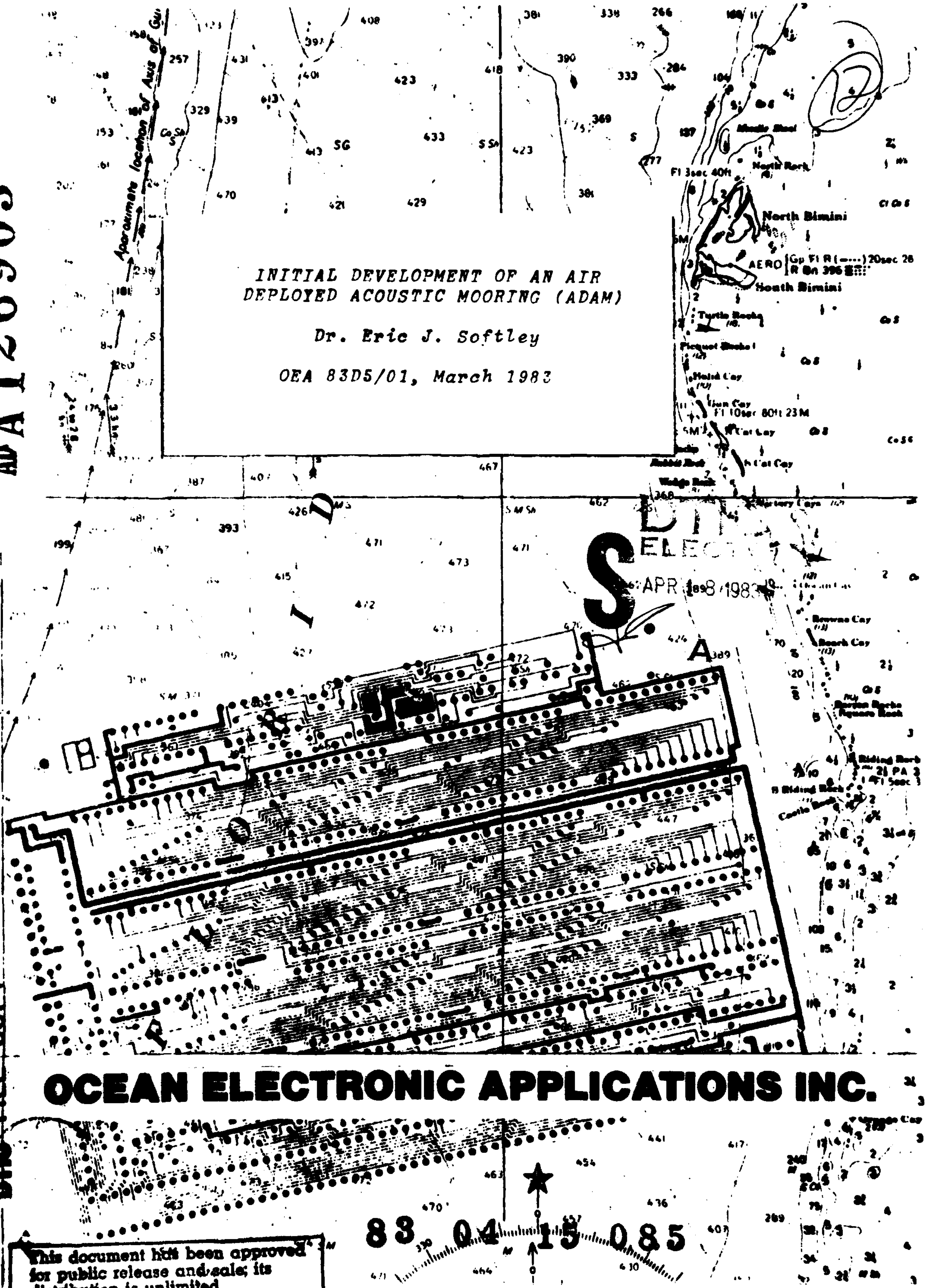
END
DATE
FILMED
6 83
DTIC


1.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

INITIAL DEVELOPMENT OF AN AIR DEPLOYED ACOUSTIC MOORING (ADAM)

Dr. Eric J. Softley

OEA 83D5/01, March 1983



OCEAN ELECTRONIC APPLICATIONS INC.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER OEA 83 D 01	2. GOVT ACCESSION NO. AD-A126 903	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Initial Development Of An Air Deployed Acoustic Mooring (ADAM)		5. TYPE OF REPORT & PERIOD COVERED Final 81-82
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Dr. Eric J Softley		8. CONTRACT OR GRANT NUMBER(s) N00014-81-C-0687
9. PERFORMING ORGANIZATION NAME AND ADDRESS Ocean Electronic Applications, Inc. 50 W. Mashta Drive, Key Biscayne, Fl.		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Ocean Programs Management Office NORDA, NSTL Station, Mississippi		12. REPORT DATE March, 1983
		13. NUMBER OF PAGES 27
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS (of this report) Uncl.
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Air deployed, Deep ocean mooring, acoustic, ambient noise, satellite telemetry.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The air deployed oceanographic mooring developed by ONR for scientific measurement has been enhanced by the development of key acoustic hardware, signal processing and increased satellite telemetry capability. The new components are fully compatible with the air deployed platform. Ambient noise measurements and SUS signal reception were the requirements.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Initial Development Of An Air Deployed Acoustic Mooring (ADAM)

Contract Final Report.

Contract: N00014-81-C-0687

Performed for:

SEAS Program Office
NORDA
NSTL Station
Mississippi

Performed by:

Dr. Eric J. Softley, P.I.
Ocean Electronic Applications, Inc
Key Biscayne
Florida 33149

TABLE OF CONTENTS

LIST OF FIGURES

Introduction

The accumulation of ambient noise data, propagation data and other related environmental information has continued for many years. Many tools have been developed for the purpose. Most of these have by necessity been ship based. Large towed arrays are an example of such hardware.

The ship has a number of drawbacks, however. First it is slow so that the accumulation of data must be planned well in advance. Secondly with rising fuel and labor prices the ship operating costs can often consume a large part of the operating budget.

For some time there has been a fragmented activity on the use of airborne hardware. The concept is that the aircraft gives both a reduced cost and a much faster reaction time. Development of air deployed moored and drifting buoys has given rise to the possibility of obtaining some of the acoustic data by aircraft based data systems.

With this in mind the auther has been working for several years on the development of an air launched environmental data buoy ADOM. This development, sponsored by the Office of Naval Research, has involved a number of contributors, including the Woods Hole Oceanographic Institution, E.G.& G. and the Naval Air Development Center. Each had a specific technical area of responsibility. In the case of the author this has included all electronic and sensor development. Of specific interest is an all CMOS processor capable of low power processing of data from many sensors incorporated into a single conductor mooring cable.

This platform capability suggested the extension of the performance to include acoustic signal reception and analysis. Under contract to NORDA hydrophone array components, i.e. hydrophone-amplifier units and frequency multiplexing transmission have been designed and tested. In addition high powered satellite communication hardware has been designed, built and tested at sea. Thirdly a processor, capable of high resolution frequency analysis and designed around a proven low powered CMOS microcomputer was conceived and received some design activity.

The contracted activity was intended to be the initial phase of a multi year development. As such a number of independent items received some attention. These were:

1. Hydrophone and amplifier design.

2. Multiplexing scheme.

3. Test of single phone and multiplexer.

4. Acoustic processor.

5. Satellite study.

Multiplexed Hydrophone Development.

The hydrophone is designed around cylindrical piezoceramic elements. The elements are 1.5 inches dia. and 0.5 inches long and are capable of withstanding the ocean hydrostatic pressure. They are etched as two half cylinders and the summed signal taken. Four of these elements are added to provide a high output, low capacitance array. The elements are mounted onto a cylindrical structure which houses the electronics and carries the tension of the mooring. The end caps interface the hydrophone to the cable and are removable. Center pin (gold plated) carry power and signals to and from the assembly (see figures 1 and 2). The overall package is covered by a polyurethane blanket. The total package then is a polyurethane sealed assembly which has been integrated into the cable in such a way that the structure carries the full tension of the oceanographic mooring. The final dimensions of the hydrophone are 1.75 inches dia. and approximately 7 inches long.

Internal to the hydrophone structure are the shaping preamplifier and the frequency multiplexer (see figure 3). The preamplifier has seven stages. The first two use very low noise JFET transistors to provide 32 dB gain and a high input impedance for the elements. This noise level of the front end is about 5nV per square root of the bandwidth. The actual noise of the amplifier is a sum of the front end FET noise and the resistor used a a bias stabilizer. This resistor provides the majority of the wideband noise. This is, however, dependent on the source capacitance. In practice the source resistor provides the low frequency noise and the FET the upper frequency noise. A careful match of the FET noise and gain prevents the first CMOS amplifier stage from contributing additional noise. Figure 4 shows the amplifier noise with the input gage replaced by an equivalent capacitor.

The next stage is a 4dB gain 5Hz high pass 2nd order filter which attenuates the signals below 10 Hz and help to decouple buoy motion from the system. The fourth stage is a shaped amplifier which is flat 10dB

gain to 50 Hz and then increases gain at a rate of 6 dB/octave for increasing frequencies. A flat 18 dB gain stage is followed by a fourth order low pass filter which attenuates signals above 600 hZ. The total amplifier characteristic is shown in Figure 5.

The amplifier stages are all constructed using CMOS amplifiers. These have sufficient bandwidth for the rather limited frequency response desired and have the distinct advantage of allowing linear signals over the whole amplitude of the supply voltage. This allows a maximum of signal before clipping and a corresponding maximum of dynamic range. It is intended to allow the best coverage of the expected ambient noises of interest. The characteristic of the amplifier was developed after discussion with Jack Shooter of the University of Texas and a result of his experience with ambient noise measurement.

The amplifier described above is built onto a small PC board sized two inches by one inch. It forms half of the total electronic assembly The other half is the frequency generator and coupler to connect it to the cable. It consists of a VCO producing a variable frequency square wave,a wave shaper and a buffer amplifier to drive a coupling transformer. Frequencies generally 20 KHz apart have been used with the lower frequency of 80 KHz and an upper limit of 200 KHz. 10 Khz spacing could be used to give a total of 13 hydrophones. Figure 6 shows the demultiplexer arrangement.

The frequency demodulator consists of five PLL pairs. The first PLL of each pairs locks onto the frequency of interest and rejects the others, including harmonics. The second PLL of each pair provides the demodulation. By using identical VCO components between the demodulator and the generator inside the hydrophone good signal linearity is maintained.

The dynamic range of the system is determined by the electronic noise and by the maximum usable signal. With a 5 Volt supply to the hydrophone a signal of some 4 dB can be used in the linear range. With the element replaced with an equivalent capacitor the noise level is determined as -74 dB at 100 Hz rising to -70 dB at 600 Hz. This gives a dynamic range of 74 to 78 dB. If a 12 bit digitizer is used in the processor this dynamic range is greater than needed.

The dynamic range of the multiplexer has been determined separately. Over the frequency range of interest this range is over 90 dB. Figure 7 shows the measured multiplexer/demultiplexer noise (FS=3dB). Hence the total system range could be increased significantly by reducing the preamplifier gain. However low end response would be lost and this is undesirable at this point.

In addition to the ambient noise preamplifier a modified version was designed for use with SUS charges. Here the front end frequency response is modified to allow operation with the sharply rising signal developed by the charge. Two separate designs were developed with two distinct compromises in the response. The first eliminates the

FET front end which results in 12 dB octave rolloff in the first stage and 24 dB rolloff by stage two. The front end noise is increased, however. By retaining the FET a 6dB rolloff can be achieved in stage first stage with the lower noise capability.

Gain and phase measurements for all stages were measured for both SUS designs. Figures 8 through 11 show these characteristics. In determining the reponse of the amplifier to the SUS transient it is important to recognise that each stage must be considered since saturation levels and amplification vary for each stage.

As originally proposed it was intended to install a hydrophone into a candidate cable and test it at sea. As part of the discussions with UT personel it was felt that a more reasonable action would be to calibrate the hydrophone/multiplexer combination in the facilities of the NAVY at USRD (Orlando) Hence a prototype was built and a suitable cable for interfacing with their tank fabricated. This hydrophone was different in that an additional capacitor was added (in parallel with the element) to reduce its sensitivity.

The results of the calibration are shown in figure 12. The response is some 6dB below the original design so removal of the capacitor would give very close to the desired response. The results are used to give the system performance of figure 13 where the range of noise specified by UT-ARL is compared with the calibrated and extrapolated performance.

It is worth observing that in order to calibrate this system in the USRD tank it was necessary to extend the normal measurement technique used by the facility. The system has such high sensitivity that the signals reach saturation at much lower levels than nomally used. At a level consistent with linear operation of this system it was necessary to use a Nicolet spectrum analyser to read the signals from the reference hydrophone. The signal was comparable in level with the 60 Hz noise level. With the increased sensitivity with the attenuating capacitor removed the situation will worsen.

The situation in the USRD tank is shown in figure 14. The hydrophone noise with the tank evacuated is shown and the noise when the tank is filled with water. In addition the transient noises could far exceed those shown.

For future hydrophone systems it will be important to use a low noise period to calibrate. The spectrum analyser will allow the calibration in this facility.

FFT Processor Development

In the ocean it will be necessary to somehow reduce the data to some useful form before telemetry. For this purpose it is intended to combine the arrav with a FFT processor. When this original study was proposed it was intended to obtain a first prototype of a processor being developed by RCA for ONR. This would be combined with the authors CMOS microcomputer to provide an all CMOS system. The RCA processor did not appear to have the performance required, however. Therefore some time was spent in conceiving a FFT processor which would provide sufficient information. A single pass system was conceived. In this system the data is recorded in digital form and stored in the computer memory. This data would then be played back at accelerated pace through a combined filter AGC system. The filter is a transverse filter combination which can be controlled in frequency and bandwidth. The narrowest combination is about 1/10 octave (6dB).

In discussions with UT-ARL the request was made to improve on this resolution. The system shown in figure 15 was devised. With the filter bandwidth set accordingly the signal is passed through the filter and then heterodyned with a synthesized signal, filtered and then rerecorded. A second pass can then be made with a second frequency translation and a fine line structure of the signal over the original bandwidth can be determined.

It should be noted that the system is quite flexible in its operation. In its simplest form with one pass only 128 bins of equal fractional octave are possible by keeping the filter fixed. Bins would vary from 0.3 Hz at 10 Hz to 18 Hz at 600 Hz. With a controlled bandwidth and playback speed it is possible to make the 128 bins constant at about 5 Hz.

In the double pass operation each bin can be again divided. A maximum of 64 bins each pass gives a total of 4096. Thus with a fixed filter the resolution improves to about 0.65 Hz at the worst point. Using a controlled process equal bandwidth bins of about 0.15 Hz could be achieved. Of course all bins need not be selected if specific frequencies were of interest.

It will be noticed in the block diagram that a FIFO memory follows the AD converter. This is used, together with a comparator to store data before recording. This allows the detection of SUS charge signals and recording of the total signal with no front end loss.

Certain of the more involved sections of this processor have been designed. In particular the DMA control which allows the memory to playback and record in an overlapping manner (during superheterodyning) has been designed. Most of the remainder of the system exists in various other system. No hardware has been constructed however.

Telemetry Transmitter Development

As originally proposed the study intended to compare the usefulness of the LES9 satellite with FLTSATCOM satellites. Preliminary data indicated that a significant improvement in data error rate could be achieved by using the latter. However discussion with Pete Traas indicated that FLTSATCOM had a high use rate and that availability for experimental purposes was not generally encouraged.

Our experience with LES9 had indicated that performance on the wide band mode was as published. The improvement in S/N in the medium and low bandwidth modes was very much below expected. Apparently the lower modes use the wideband front end receiver and the noise reduction is just not achieved. With 20W power and a 3dB antenna on the buoy a data rate of 1200 Baud could be achieved with an error rate of .04%. The downlink S/N was about -3dB and the noise was determined to be from the satellite.

The higher data rates desired for acoustic data telemetry (4800 min) required use of the medium band mode. This requires about 80W transmitter power. Use of a higher gain antenna is not practical because of the buoy motion. The transmitter used with ADOM was 20W output power designed by O.E.A. Inc. for that contract. It uses stripline power amplifier design techniques and the design was achieved without major complications. A complete redesign was needed for the higher power since the particular transistors available did not allow simple addition of a new stage. A new, thicker base, which provides heat sinking for the power transistors was also necessary.

A major problem occurred in that at the higher power level considerable feedback occurred even with careful isolation of the stages. This is mainly the result of the very compact packaging since the total transmitter is housed in a short cyclindrical addition to the base of the antenna (see figure 16). Additional isolation hardware and some redesign did result in an operating transmitter. Figure 17 shows the measured output power.

The new transmitter was tested on the rooftop of the laboratory on Key Biscayne, Florida. Results indicate that with a data rate of 2400 baud data error rates of .01% were possible. Figure 18 tabulates the results. While the satellite angle is important it was apparent during the tests that local noise transients did occur quite regularly and would not be affected by the data rate. Improved data rates would require modifications to the shore receiver and this was not attempted at this time. This transmitter was duplicated (under another contract) and the two transmitters used in a dual sea trial. One of the two did not transmit due to damage to the power cable during launch. The second transmitter did perform but at reduced power from that expected. It was later determined that there was RF pickup in the battery packs in the circuitry designed to protect the Lithium batteries from being discharged at too high a rate. This has since been eliminated and no problems are expected in future tests.

Conclusions

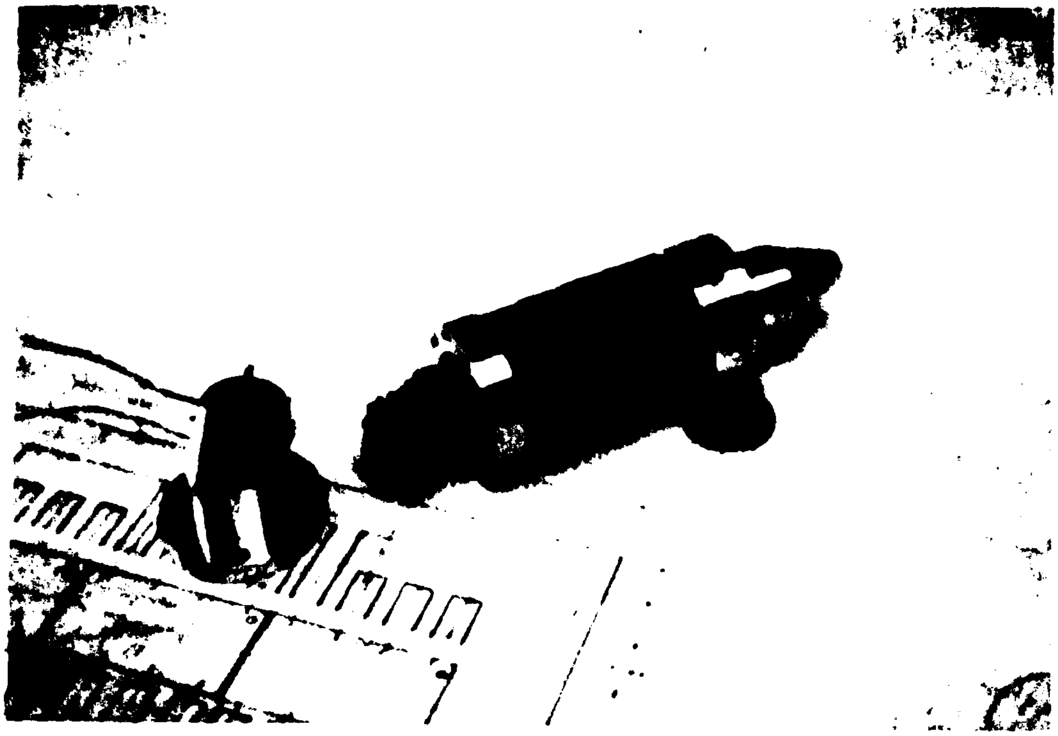
The harware development described here has resulted in a set of devices which can considerably enhance the ADOM platform and in particular allow the direct measurement of ambient noise and SUS signal propogation from an air deployed system.

In particular the development program has resulted in the complete design for a hydrophone/multiplexer that has been calibrated and lab tested. Designs for both ambient noise and SUS signals exist. We also have two hydrophones available for future work.

In order to provide signal processing on board the buoy a design for a FFT processor which uses batch processing of the ambient noise data and by using multiple pass processing can achieve resolutions of some 0.15 Hz bandwidth bins over the range of 10 Hz to 1000 Hz has been accomplished. This system uses the ADOM buoy processor as a base and is about 99% CMOS in construction for minimum power consumption.

Two high powered transmitters suitable for satellite transmission have been built and are available for extended capability testing. The design has been tested in roof tests at Key Biscayne and has achieved the desired accuracy. In sea tests a problem with support hardware prevented all but a limited amount of data to be received.

FIGURE 1. HYDROPHONE ASSEMBLY



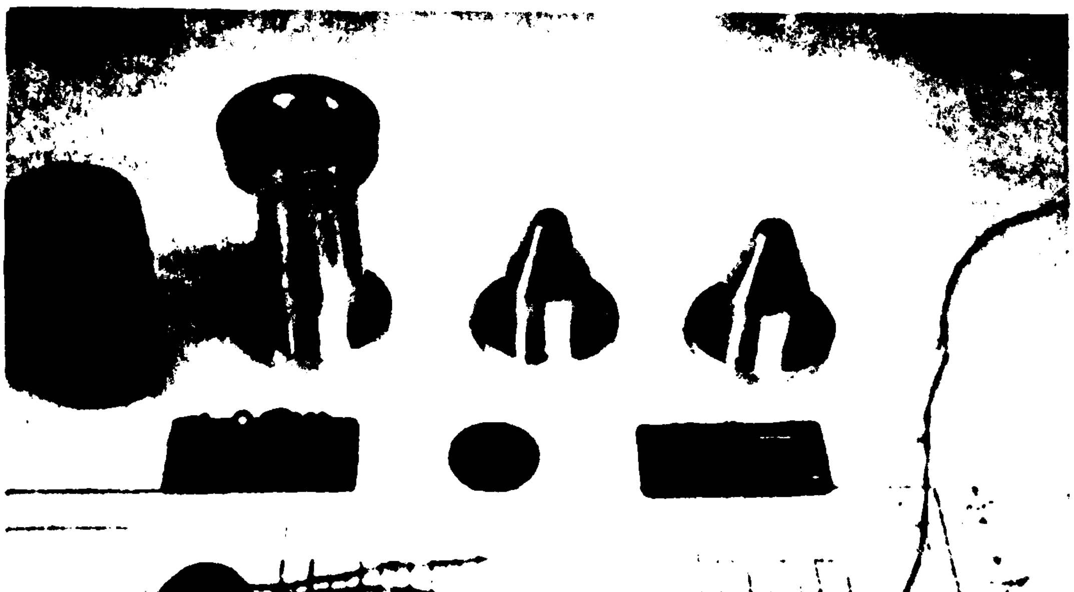


FIGURE 2. HYDROPHONE COMPONENTS

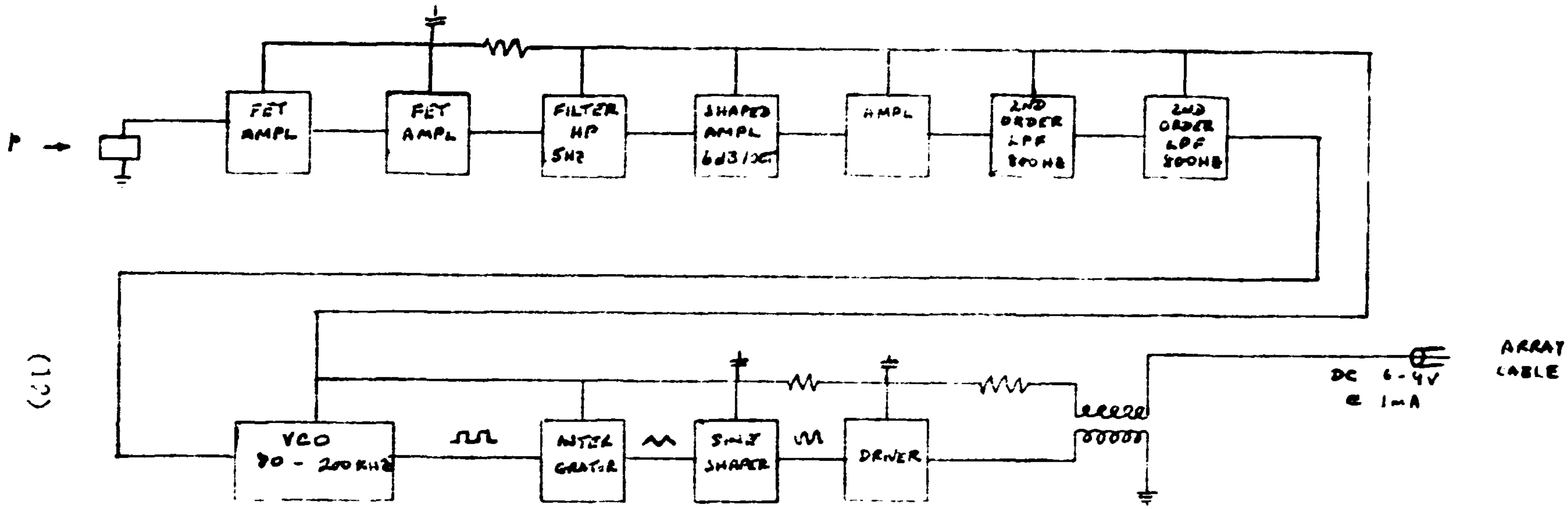


FIGURE 3. ELECTRONIC ARRANGEMENT OF HYDROPHONE AMPLIFIER/MULTIPLEXER

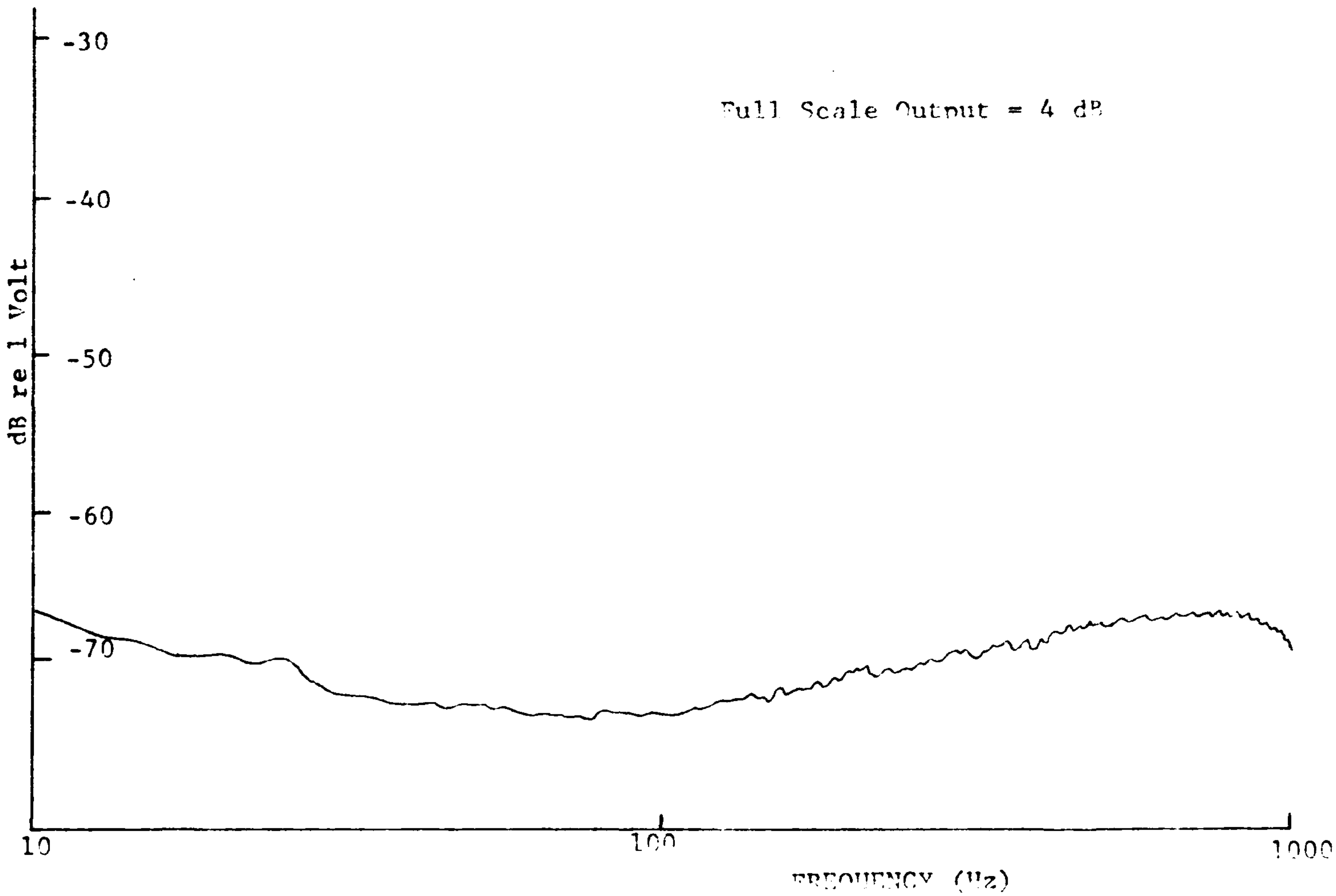


FIGURE 4. AMPLIFIER NOISE (AMBIENT NOISE HYDROPHONE)

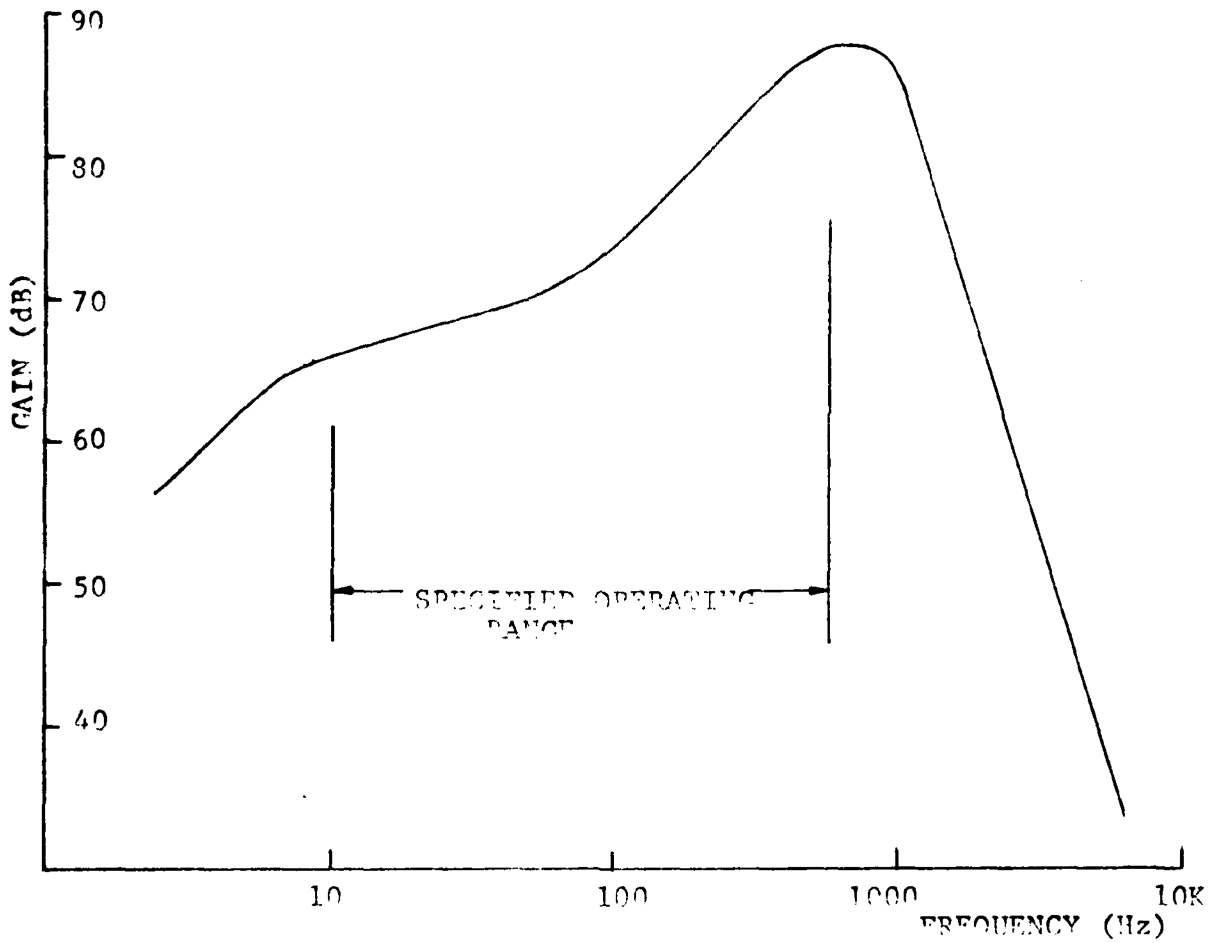


FIGURE 5. AMPLIFIER GAIN (AMBIENT NOISE HYDROPHONE)

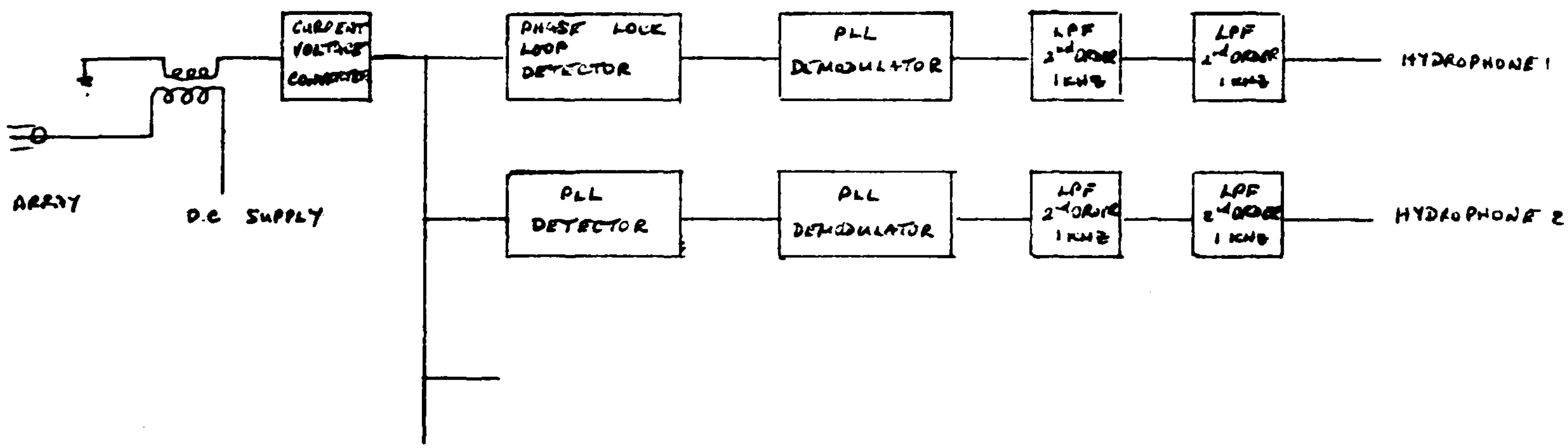


FIGURE 6. ELECTRONIC ARRANGEMENT OF DEMULTIPLEXER

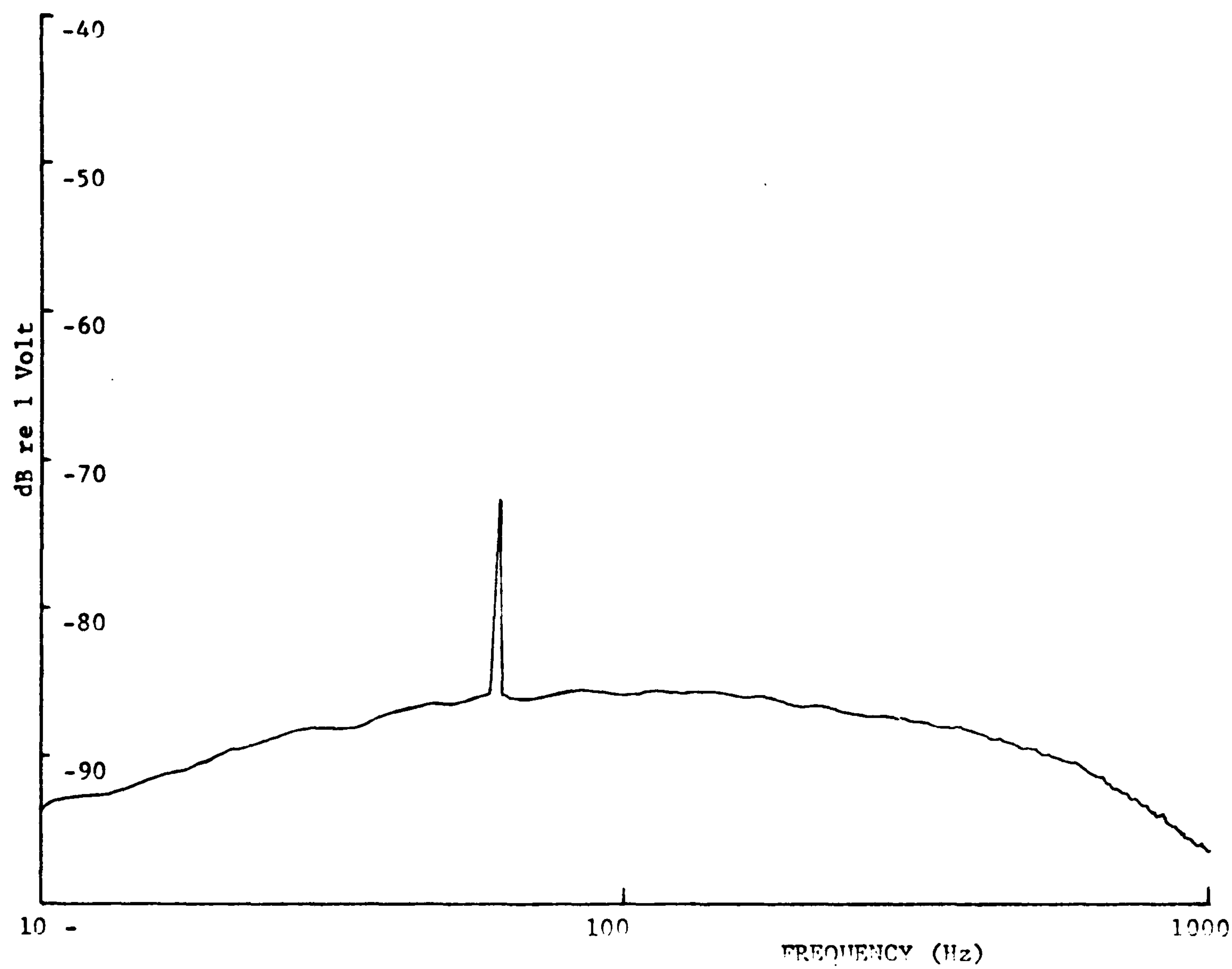


FIGURE 7. MULTIPLEXER/DEMULTIPLEXER NOISE

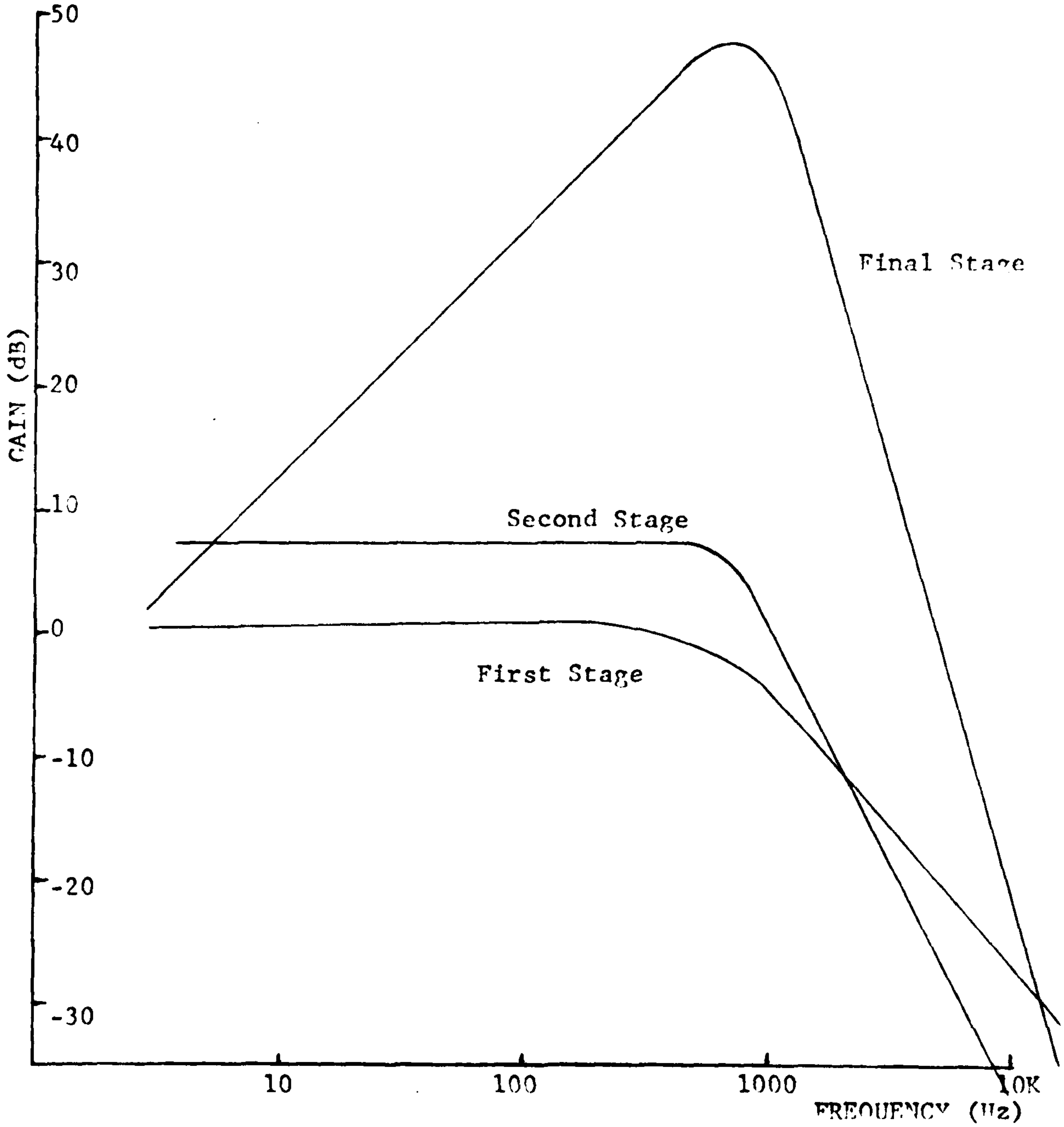


FIGURE 8. SUS 1 AMPLIFIER GAIN

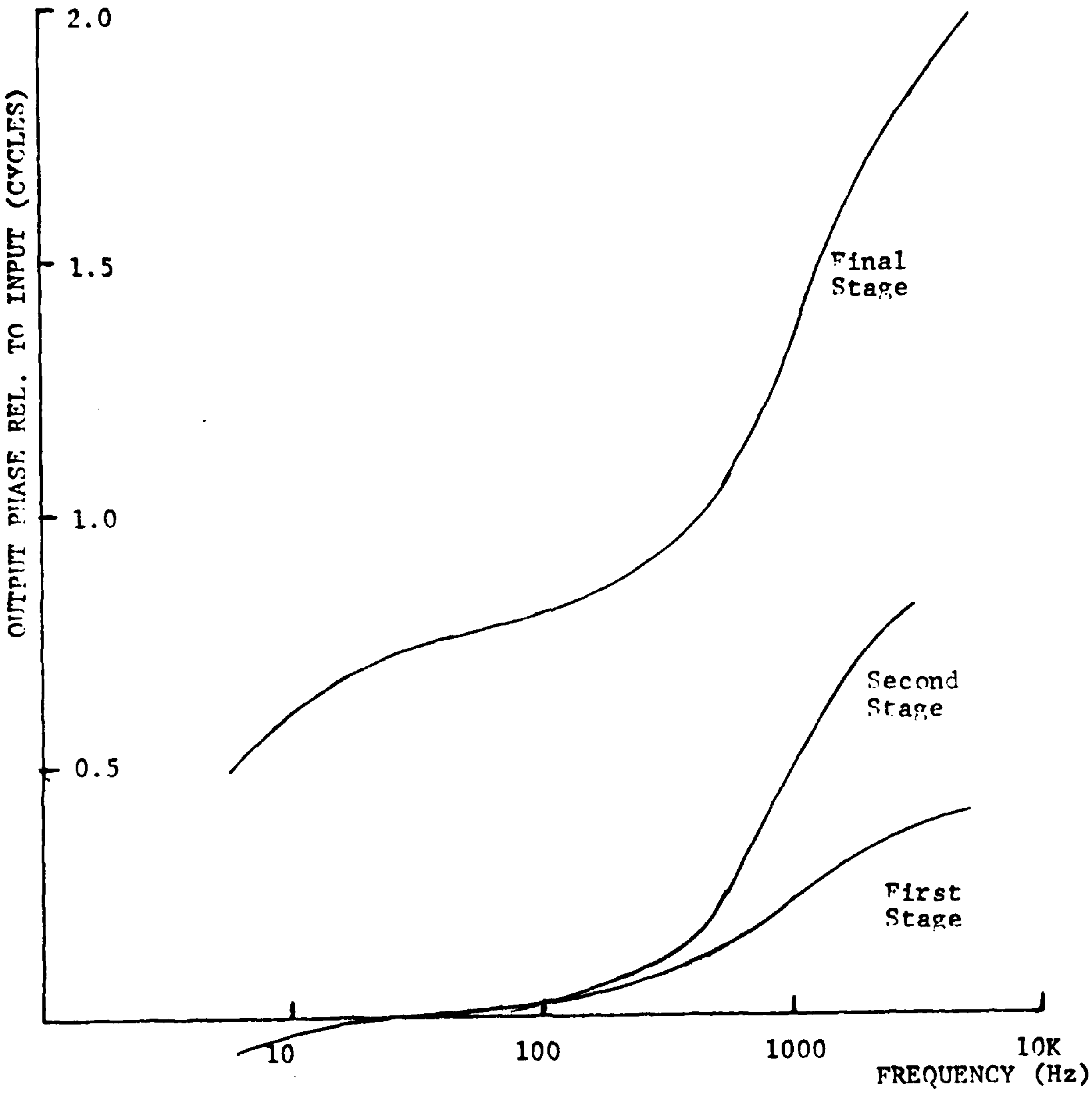


FIGURE 9. SUS 1 AMPLIFIER PHASE SHIFT

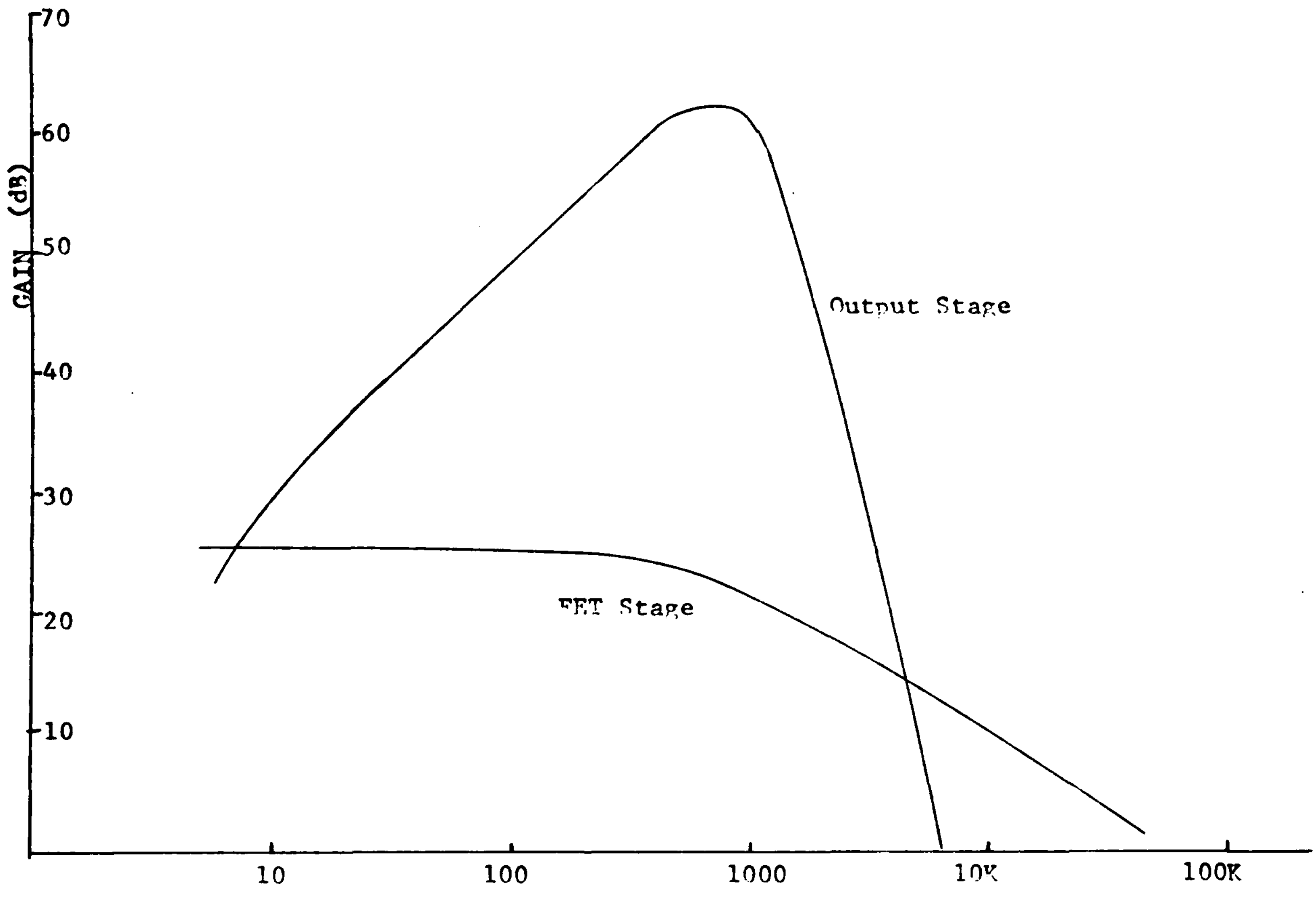


FIGURE 10. SUS 2 AMPLIFIER GAIN

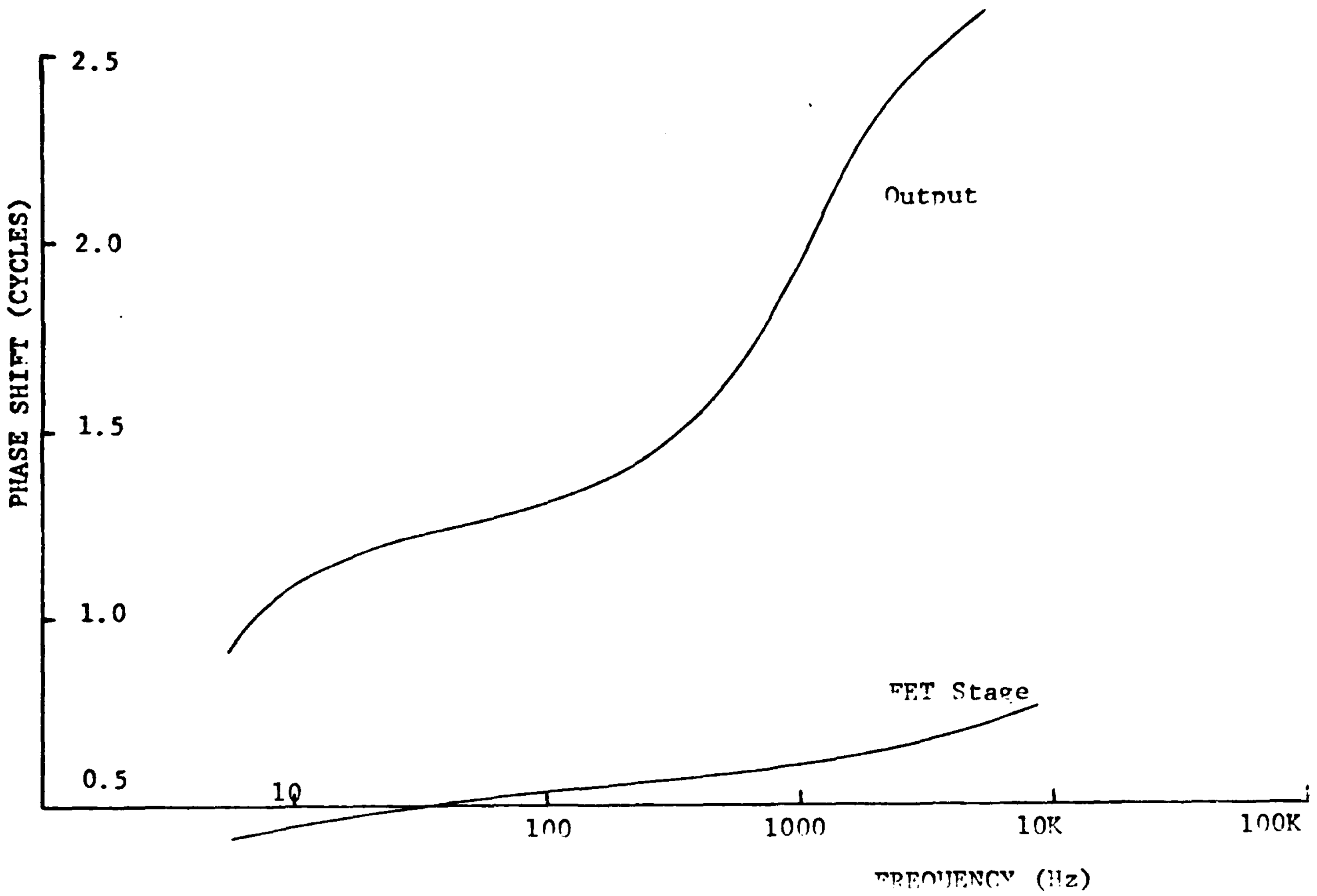


FIGURE 11. SUS 2 AMPLIFIER PHASE SHIFT

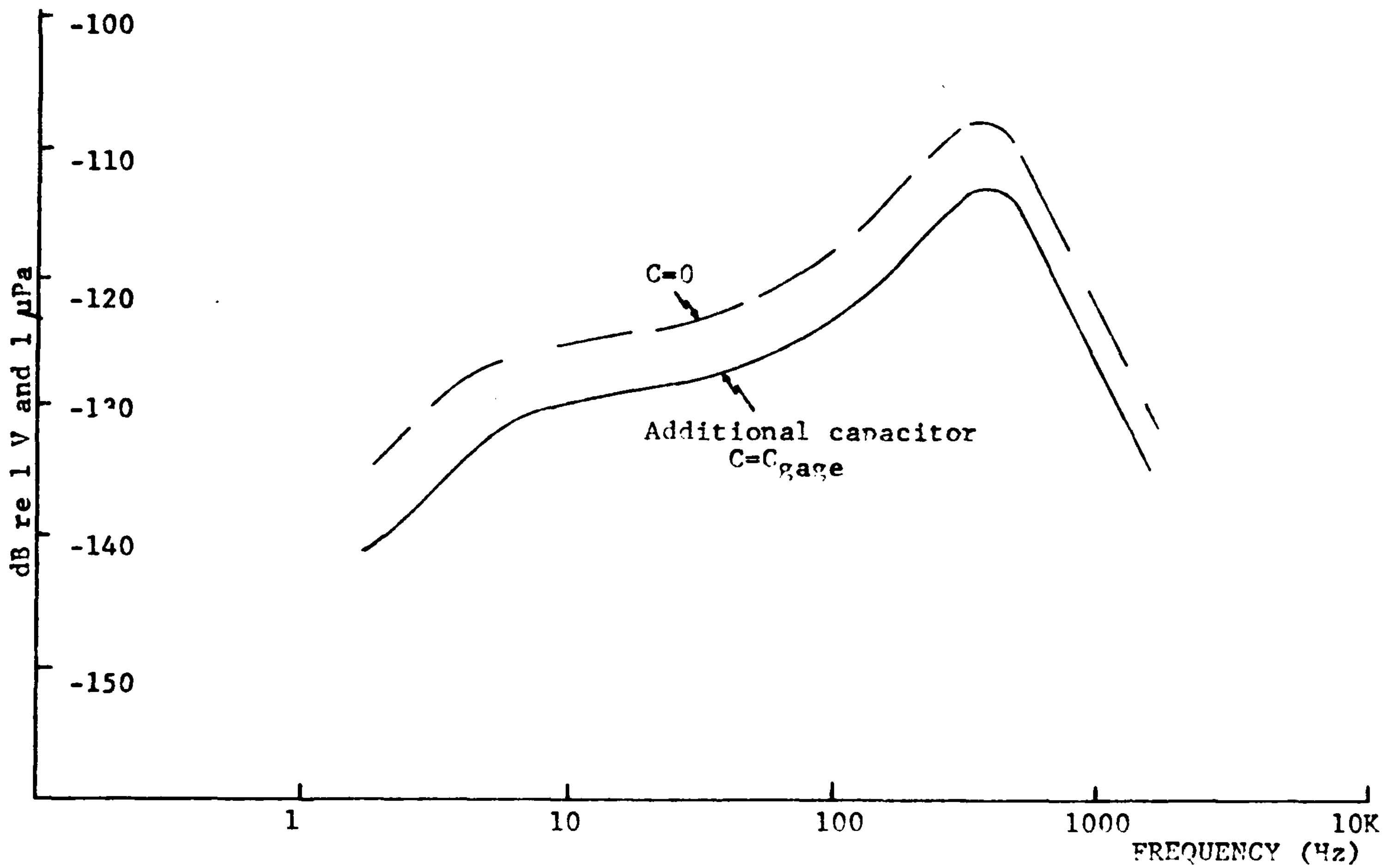


FIGURE 12. MULTIPLEXED HYDROPHONE CALIBRATION

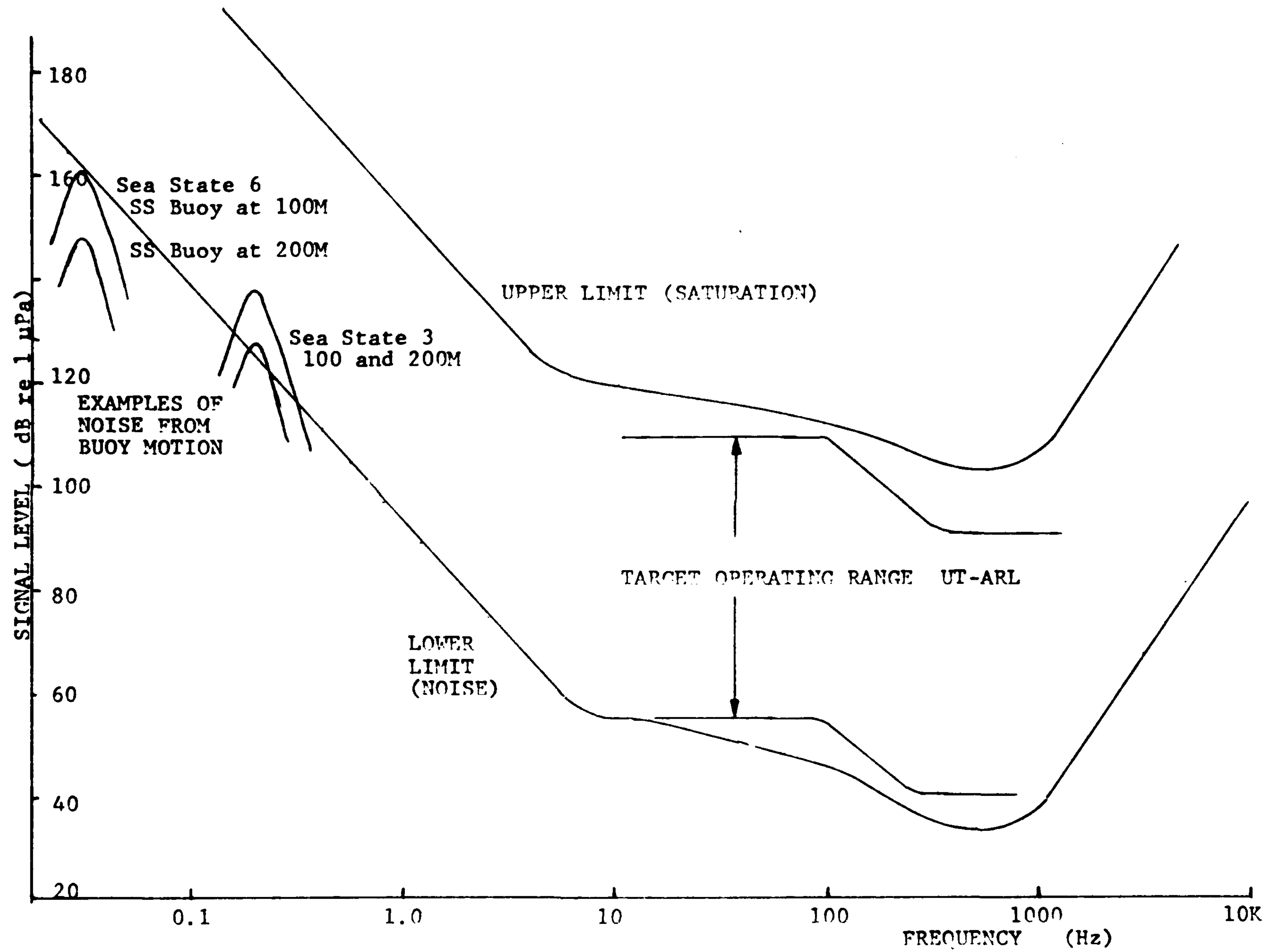


FIGURE 13. HYDROPHONE PERFORMANCE ON ADOM BUOY

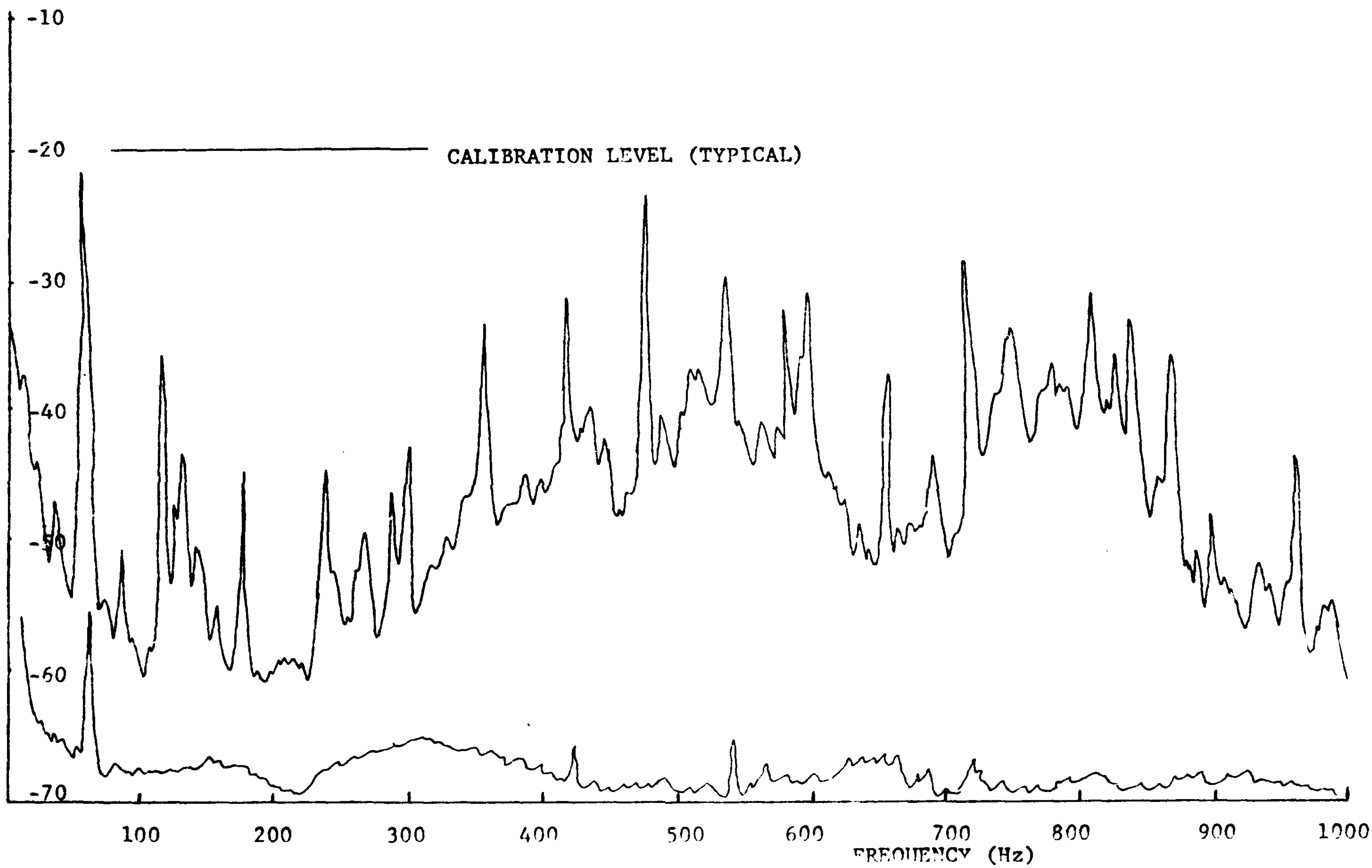


FIGURE 14. NOISE IN CALIBRATION TANK

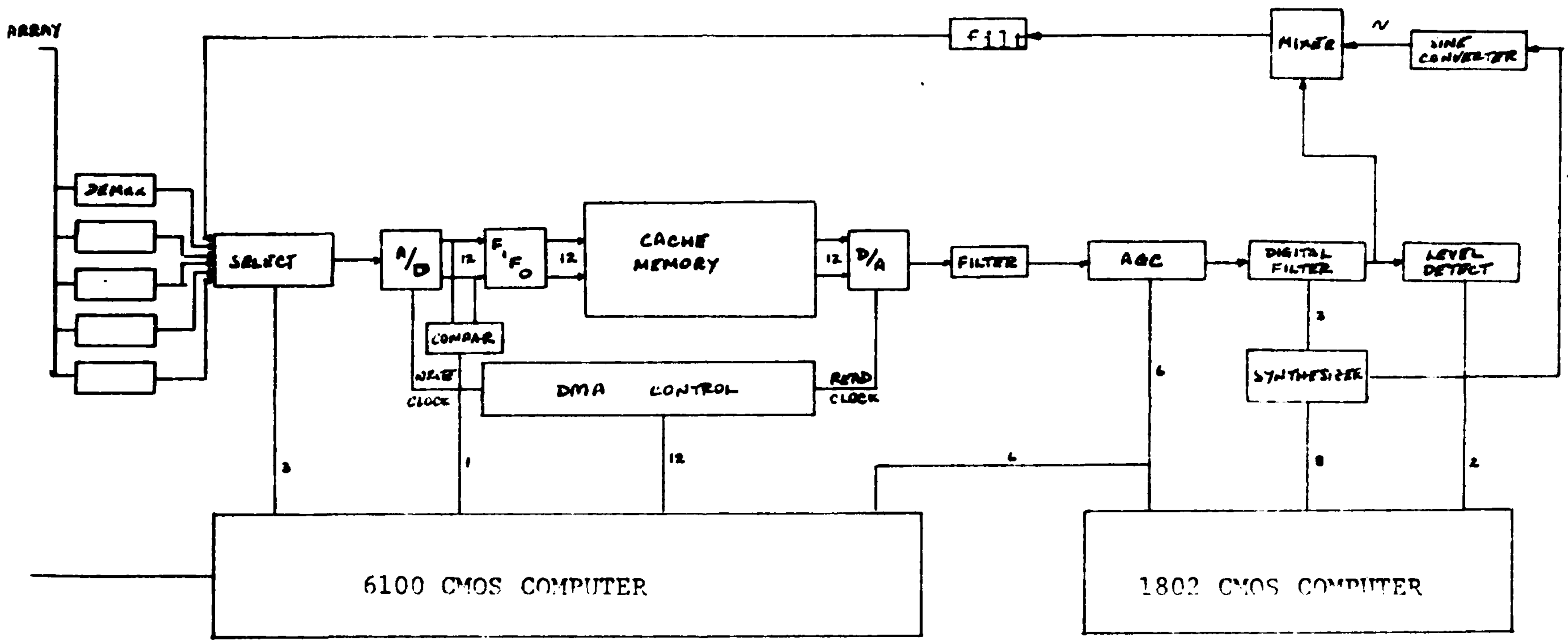


FIGURE 15. ARRANGEMENT FOR A MULTIPLE PASS FINE RESOLUTION FFT PROCESSOR FOR ADAM

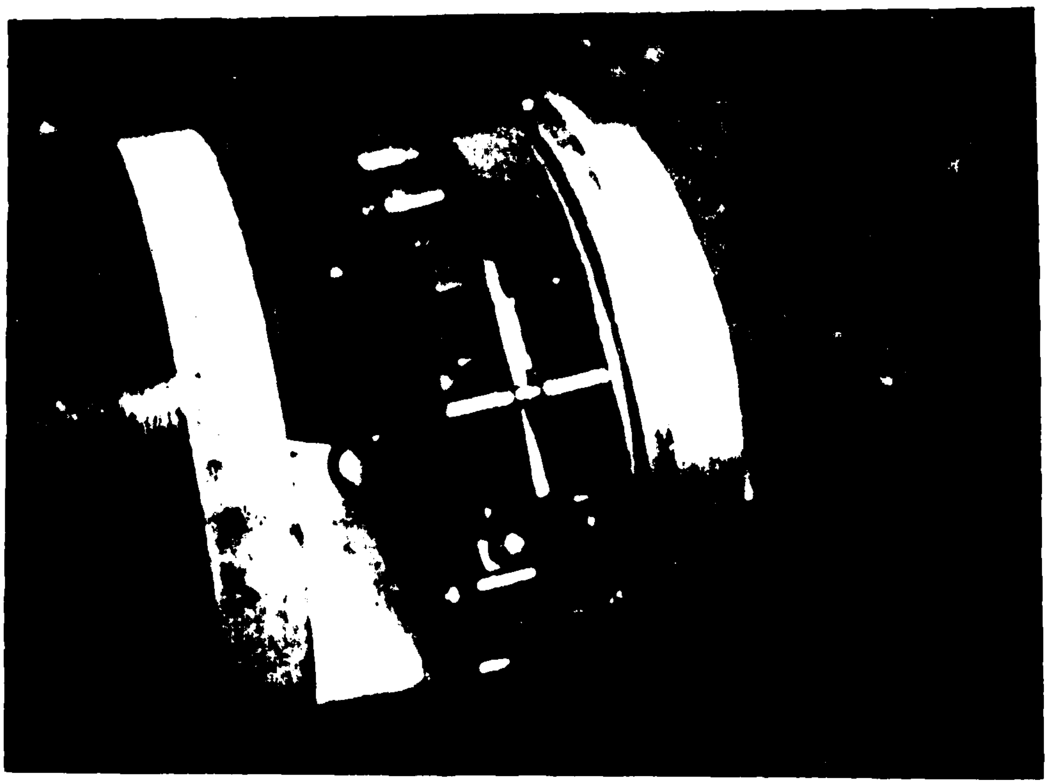


FIGURE 16. TRANSMITTER ASSEMBLY

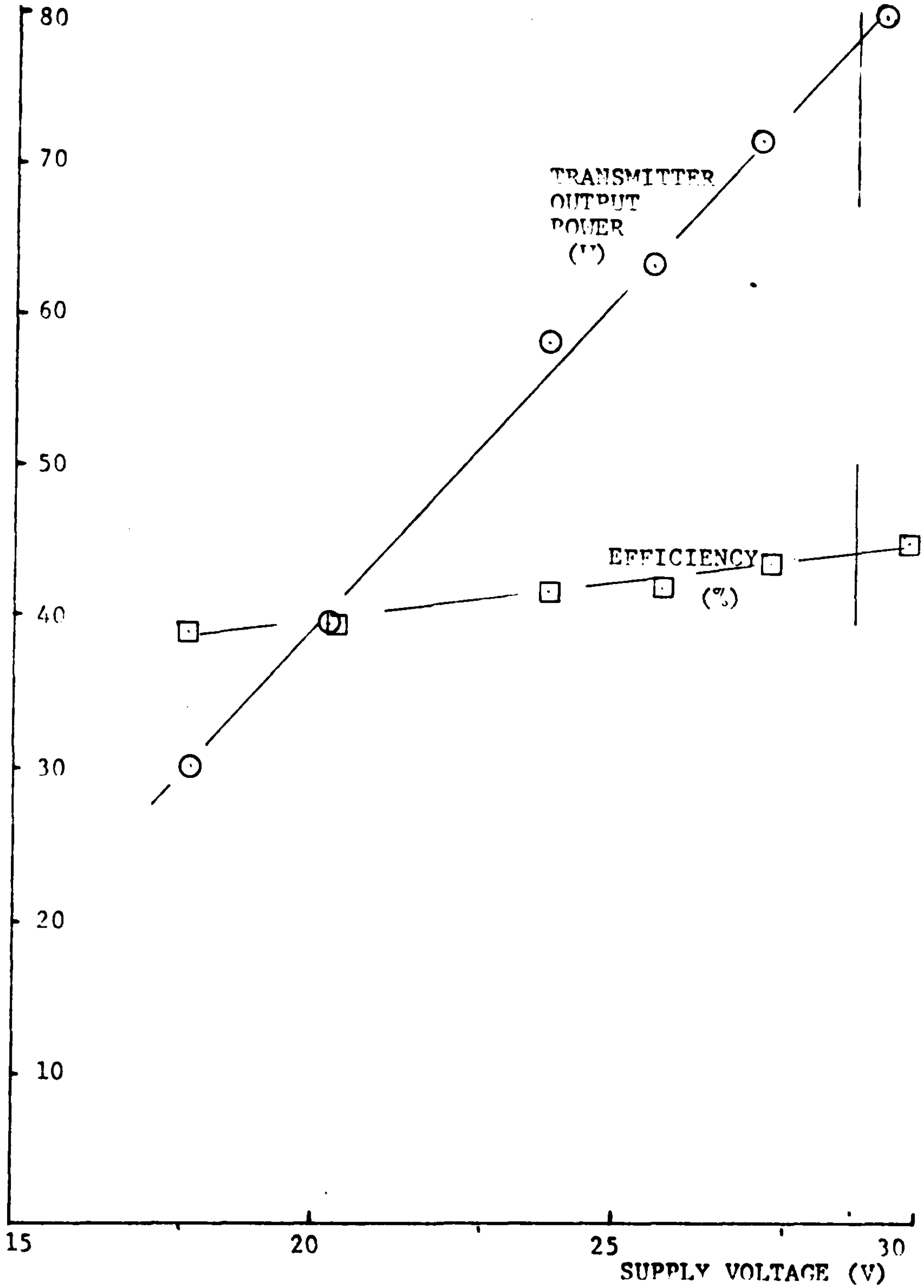


FIGURE 17. TRANSMITTER POWER OUTPUT

80 W Transmitter/ LES 9 Satellite

TELEMETRY TESTS.

Transmitter - Rooftop, Key Biscayne, Florida
10/25/82

Time (Zulu)	Satellite Latitude	Supply Voltage	Power Output	Data Rate	Sample	Error	%
1600	3S	30	80W	1200	1E4	0	0
1605		28	76W	1200	1E4	0	0
1610		26	60	1200	1E4	2	.02
1615		24	52	1200	1E4	36	.36
1620		22	37	1200	1E4	147	1.47
1700	9S	30	80	1200	1E4	1	.01
					1E4	0	0
					1E5	6	.01
1800	15S	30	80	1200	1E4	6	.06
					1E4	2	.02
					1E5	27	.03
1900	19S	30	80	2400	1E4	1	.01
					1E4	3	.03
					1E5	18	.02
2000	223	30	80	2400	1E4	3	.03
					1E4	5	.05
					1E5	12	.01

END

DATE
FILMED

5 – 83

DTIC